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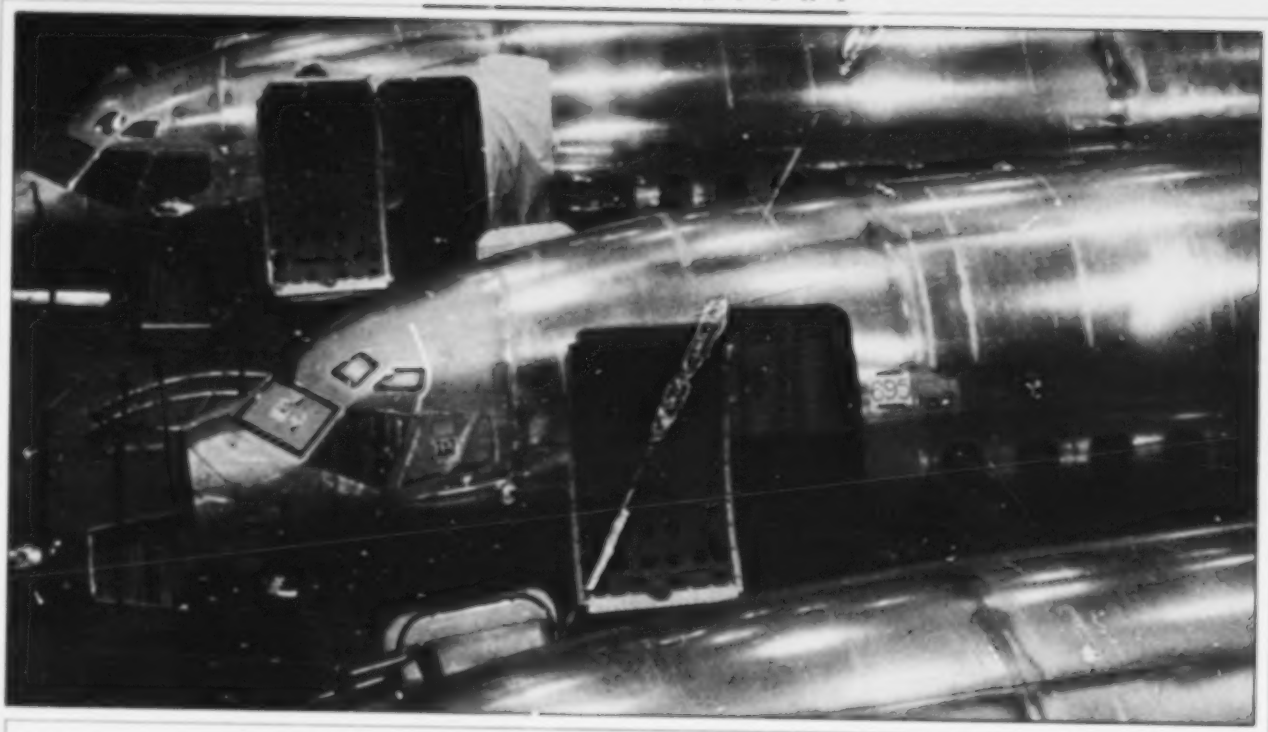

FLUORSPAR

By M. Michael Miller

1990

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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ANNUAL REPORT

FLUORSPAR

U.S.
DEPARTMENT
OF THE
INTERIOR

Manuel Lujan, Jr.
Secretary

BUREAU
OF
MINES

T S Ary
Director

September 1991

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COVER PHOTO
Boeing 767 planes using high-strength aluminum alloys. Fluorspar, aluminum fluoride, and cryolite are used in aluminum manufacture. (Photo is courtesy of Aluminum Co. of America.)

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FLUORSPAR

By M. Michael Miller

Mr. Miller, a physical scientist with 13 years of mineral experience with the Department of the Interior, has been the commodity specialist for fluorspar since 1989. Domestic survey data were prepared by Gail D. Mason, mineral data assistant; and international data tables were prepared by Harold Willis, international data assistant.

In the United States, one major producer and two small producers supplied about 11% of the Nation's fluorspar requirements. Supplementing fluorspar as a domestic source of fluorine was byproduct fluosilicic acid production from some phosphoric acid producers. Imports of fluorspar, which continued to supply most of the U.S. requirements, decreased by about 23% compared with those of 1989. Hydrofluoric acid (HF) imports were about 10% lower than reported in the previous year.

DOMESTIC DATA COVERAGE

Domestic production and consumption data for fluorspar were developed by the U.S. Bureau of Mines from voluntary surveys of U.S. operations. Surveys were conducted to obtain fluorspar mine production and shipments and fluosilicic acid production. Of the five fluorspar mining operations to which a survey request was sent, three responded, representing more than 95% of domestic shipments. Shipments for the two nonrespondents was estimated using data from contacts within the industry. Production statistics in table 1 are withheld to protect company proprietary data. Of the seven fluosilicic acid producers surveyed, seven responded, representing 100% of the quantity reported. The consumption survey was sent to approximately 93 operations quarterly and to 40 additional operations annually. Of the operations surveyed quarterly, 60% responded. Of the operations surveyed on an annual basis, 68% responded. Together, quarterly and annual responses represented 96% of the apparent consumption data shown in table 1.

BACKGROUND

Definitions, Grades, and Specifications

Technically, pure fluorspar, or the mineral fluorite, contains 51.1% calcium and 48.9% fluorine. Natural fluorite is commonly associated with other minerals such as quartz, barite, calcite, galena, siderite, celestite, sphalerite, chalcopyrite, other sulfides, and phosphates. It occurs in well-formed isometric crystals, in massive and earthy forms, and as crusts or globular aggregates with radial fibrous

TABLE 1

SALIENT FLUORSPAR STATISTICS[1]

		1986	1987	1988	1989	1990
United States:						
Production:						
Finished (shipments)[2]	metric tons	70,800	63,500	63,500	66,000	63,500
Value f.o.b. mine	thousands	W	W	W	W	W
Exports	metric tons	14,710	2,595	3,136	5,134	14,921
Value	thousands	$1,634	$308	$346	$694	$1,891
Imports for consumption	metric tons	501,478	531,530	689,139	655,590	513,921
Value[2]	thousands	$41,436	$43,935	$62,748	r$79,897	$65,938
Consumption (reported)	metric tons	525,112	542,830	r651,055	641,882	564,545
Consumption (apparent)[3]	do.	518,264	643,659	723,804	r693,121	586,856
Stocks, Dec. 31:						
Domestic mines:						
Finished	do.	W	W	W	W	W
Consumer	do.	81,531	30,310	56,012	79,347	54,991
World: Production	do.	r4,849,710	r4,816,572	r5,206,605	r5,585,712	e5,106,632

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data.

[1]Does not include fluosilicic acid (H_2SiF_6) or imports of hydrofluoric acid (HF) and cryolite.

[2]C.i.f. U.S. port.

[3]U.S. primary and secondary production plus imports, minus exports, plus adjustments for Government and industry stock changes.

texture. In crystalline form, it can be colorless or may exhibit a wide range of colors, including yellow, blue, purple, green, rose, red, bluish and purplish black, and brown. It has a hardness of 4 on the Mohs' scale, a specific gravity ranging from 3.01 to 3.60, and a melting point of 1,378° C.

Three principal grades of fluorspar are available commercially: acid, ceramic, and metallurgical. Although the specifications for individual grades are generally well defined, some variation is permitted to satisfy the requirements of individual consumers.

In the United States, acid-grade fluorspar (acidspar) contains at least 97% CaF_2. Some manufacturers of hydrofluoric acid in the United States and Europe can use 96% CaF_2 or slightly lower if the remaining impurities are acceptable. User specifications may impose limits on silica, calcium carbonate, sulfide or free sulfur, calcite, beryllium, arsenic, lead, phosphates, and other constituents. Moisture content of the dried material is preferably 0.1% or less. Particle size and distribution are sometimes specified for proper control of the rate of chemical reaction and stack losses. Very few reserves in the world can be used to produce acid-grade fluorspar without flotation processing.

Ceramic-grade fluorspar is generally marketed as No. 1 ceramic, containing 95% to 96% CaF_2, and No. 2 ceramic, containing 85% to 90% CaF_2. An intermediate grade of about 93% to 94% CaF_2 is also available. Specifications on impurities vary, but may allow a maximum of 2.5% to 3.0% silica, 1.0% to 1.5% calcite, 0.12% ferric oxide, and trace quantities of lead and zinc. Shipments of ceramic-spar are usually tailored to the specific need of individual consumers.

Metallurgical-grade fluorspar (metspar) contains a minimum of 60% effective CaF_2. In the United States, metspar is usually quoted in terms of effective CaF_2 units, obtained by subtracting 2.5 times the silica content of the ore from its total CaF_2 content. The term "metspar" is usually used to refer to material with a maximum CaF_2 content of 85%, but sometimes is used for material as high as 96%, which includes what is technically ceramic grade. Other countries may require a minimum of 80% CaF_2, which allows larger quantities of silica, usually a maximum of 15%, and other contaminants. Metspar is often traded as a lump or gravel that must pass a 25- to 37.5-millimeter screen (1 to 1 1/2 inch) and contain less than 15% of material passing a 1.6-millimeter screen (1/16 inch).

In the domestic steel industry, various shapes and sizes of briquets or pellets are being used. Generally made to consumer specifications, briquets contain varying quantities of fluorspar mixed with binders, fillers, and fluxing agents. Typically made on roll presses and ranging in size from that of a peach seed to a 5-centimeter square, briquets contain 25% to 90% CaF_2 and steel mill waste ingredients, such as mill scale, flue dust, shredded scrap, iron ore fines, and manganese ore fines. The most popular binders are molasses and lime, which do not require baking ovens. Imported briquets are often made from fines accumulated during metspar preparation and from flotation concentrates. Pellets have been made on balling machines using sodium silicate binder.

Geology-Resources[1]

Fluorspar occurs in a wide variety of geological environments, which indicates that deposition takes place in a number of different ways. From an economic standpoint, seven of the most important modes of occurrence are as follows:

1. Fissure vein deposits commonly occur along faults or shear zones and are the most readily recognized form of fluorspar occurrence in the world. Although the vein structure may be persistent, the fluorspar mineralization commonly occurs as lenses or ore shoots separated by barren zones. Fissure veins occur in igneous, metamorphic, and sedimentary rocks.

2. Stratiform, manto, or bedded deposits occur as replacements in carbonate rocks. Some beds are replaced adjacent to structural features such as joints and faults. Frequently, there is a capping of sandstone, shale, or clay.

3. Replacement deposits in carbonate rocks along the contact with acidic igneous intrusives are another common type of deposit. Deposits do not have to be the result of contact metamorphism, but may be introduced later, following the contact zone as a conduit and replacing the limestone.

4. Stockworks and fillings in shear and breccia zones are another form in which fluorspar occurs. The Buffalo deposit in the Transvaal consists of a network of fluorspar veinlets in sill-like bodies that are inclusions in the granite of the Bushveld complex.

5. Carbonatite and alkalic rock complexes may have fluorspar at their margins. Fluorspar grades are not usually sufficient to be economic, but the Okorusu deposit in Namibia is made up of a number of bodies of fluorspar in limestones, quartzites, and related rocks that have been intruded and metamorphosed by an alkaline igneous rock complex.

6. Residual deposits of fluorspar are formed in clayey and sandy residuum that results from surficial weathering of fluorspar veins and replacement deposits. These deposits may be the sources of metallurgical-grade fluorspar. They include detrital deposits blanketing the apex of veins and the upper portions of the veins themselves that have been weathered to depths of 30 meters or more.

7. Fluorspar may also occur as a major gangue mineral in lead and zinc vein deposits. Two operations in the Parral area of Mexico have treated the tailings of lead-zinc mines to recover fluorspar from previously discarded gangue minerals.

Identified world fluorspar resources are approximately 365 million metric tons of contained fluorspar. As might be expected, the countries with the highest production have the largest fluorspar reserves, although their production ranking does not necessarily mirror their reserve ranking. World resources of equivalent fluorspar from phosphate rock are approximately 325 million metric tons, which includes about 32 million metric tons from domestic phosphate rock.

Technology

Mining.[2]—Mining methods vary according to geologic conditions at individual deposits around the world. Deep deposits usually require underground techniques, while wide, shallow deposits employ open pit methods. If the ground is unable to support underground mining, open pit methods may be used even though overburden removal might be substantial. In some cases, open pit methods are used until the mining reaches a practical production limit because of excessive waste removal. Mining then moves underground.

Narrow vein mining is often done by shrinkage stoping and open stoping where strong walls occur, while stratiform or

TABLE 2

WORLD FLUORSPAR RESERVES AND RESERVE BASE[1]

(Thousand metric tons contained CaF_2, 100% equivalent)

Country	Reserves[2]	Reserve base[3]
North America:		
Canada	2,000	5,000
Mexico	19,000	23,000
United States	W	10,000
Total	21,000	38,000
Europe:		
France	10,000	14,000
Italy	6,000	7,000
Spain	6,000	8,060
U.S.S.R.[e]	62,000	94,000
United Kingdom	2,000	3,000
Total	86,000	126,000
Africa:		
Kenya	2,000	3,000
Namibia	3,000	5,000
South Africa, Republic of	30,000	36,000
Total	35,000	44,000
Asia:		
China[e]	27,000	46,000
Mongolia[e]	50,000	59,000
Thailand	1,000	2,000
Total	78,000	107,000
Other countries	19,000	25,000
World total	239,000	340,000

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]The definitions of reserves and reserve base are published in U.S. Geological Survey Circular 831, "Principles of a Resource/Reserve Classification for Minerals," which is reprinted in the annual U.S. Bureau of Mines, Mineral Commodity Summaries.

[2]Recoverable CaF_2 at the demonstrated level (measured plus indicated).

[3]The reserve base includes demonstrated resources, reported in terms of 100% CaF_2, that are currently economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources).

bedded deposits use room-and-pillar patterns. Replacement and fissure vein deposits are mined with shrinkage stoping or cut and fill methods if they are deep, narrow occurrences. They may also be mined by open pit or strip-mining techniques when they occur near the surface and have competent sidewalls. The replacement and stockwork deposits in the Republic of South Africa, the carbonatite deposit in Namibia, and most of the fissure veins in Thailand are mined with open pit methods. However, replacement deposits in Mexico are extracted by stoping or cut-and-fill methods.

Beneficiation.—Most fluorspar must be upgraded for marketing. Metspar is often produced by hand sorting of high-grade lump crude ore, followed by crushing and screening to remove most of the fines. In the case of fluorspar ores of lower grade and/or ores with relatively coarse interlocking of minerals, gravity concentration processes are used based on the specific gravity above 3.0 for spar and below 2.8 for most gangue minerals.

Heavy-media cone and drum separators are particularly effective in the 37.5 by 4.75 millimeter (1 1/2 by 3/16 inch) size range, either for producing metallurgical gravel or for preconcentrating crude ore for flotation feed. For the finer sizes, the heavy-media cyclone process is frequently used. The high capacity and low operating cost of heavy-media methods give very satisfactory results. Ores as low as 14% CaF_2 can be preconcentrated to yield a flotation feed of 40% CaF_2 or more. In the process, lead and zinc sulfides and barite concentrate with the fluorspar, which enriches the flotation feed with these valuable minerals. In some cases, washing plants are also used prior to flotation to remove clay or manganese oxides (wad).

Ceramic and acid grades of fluorspar are produced by multistage froth flotation. Ore from the mine is crushed and ground to proper size; care is taken not to over grind and cause fluorspar to be lost in the slimes. If lead and zinc sulfides are present, they are preferentially floated off with xanthate collector. After this process is completed, all the easy floating fluorspar is removed in a quick pass through a flotation circuit and sent on to the cleaner circuit. The tailings are discarded. The middling product is reground to separate the more finely interlocked grains of fluorspar and gangue and passed through one or more cleaner circuits. The final products generally comprise an acid-grade concentrate and, in some cases, one or more concentrates of lower grade, which are sold as ceramic grade, or pelletized and sold as metallurgical grade. Fatty acids are used as collectors for the fluorspar. Quebracho or tannin is used to depress calcite and dolomite; sodium silicate is used to depress iron oxides and silica; and chromates, starch, and dextrin are used to depress barite. Cyanide is used to depress any remaining sulfides. Lime, caustic, or soda ash can be used for acidity control. Flotation temperatures range from ambient to 80° C.

ANNUAL REVIEW

Legislation and Government Programs

At yearend, the National Defense Stockpile fluorspar inventory was unchanged from yearend 1989. New goals were finalized in 1990 of 900,000 short dry tons (about 816,000 metric tons) for acid grade and 310,000 short dry tons (about 281,000 metric tons) for metallurgical grade.

The Defense Logistics Agency, Defense National Stockpile Center, announced the offering for sale of a portion of the 15,000 short dry tons (13,608 metric tons) of metallurgical-grade fluorspar authorized

for disposal during fiscal years 1990 and 1991. Sale was authorized of 5,000 short dry tons (4,536 metric tons) for fiscal year 1990 and 10,000 short dry tons (9,072 metric tons) for fiscal year 1991. No bids were received during calendar year 1990. Additional offerings were scheduled for May, July, and September 1991. The material offered is stockpiled near Gallup, NM. It is of nonstockpile grade and has an effective calcium fluoride content of 59%.

Depletion allowances against Federal taxes of 22% and 14%, respectively, remained in effect for domestic and foreign production by U.S. companies.

On November 28, 1990, the Illinois Wilderness Act of 1990 was signed into Federal law. The law designated seven tracts in the Shawnee National Forest in southern Illinois as wilderness and, therefore, components of the National Wilderness Preservation System. The 7 tracts total about 10,630 hectares (26,266 acres). The boundaries of the Shawnee National Forest encompass a substantial portion of the Illinois-Kentucky fluorspar district, including the operations of Ozark-Mahoning Co. The law designated 2 additional tracts totaling about 1,119 hectares (2,764 acres) as special management areas. Within these two areas, prospecting for fluorspar and associated minerals may be allowed for a period of not more than 8 years from the enactment date. If fluorspar and associated minerals are found on these lands, mining may be allowed for a 20-year period from the date of enactment. If no prospecting or mining takes place during the allotted time periods, these special management areas will be designated as wilderness and become components of the National Wilderness Preservation System.[3]

On November 15, 1990, the Clean Air Act Amendments of 1990 were enacted into law. Title VI covered stratospheric ozone protection. Chemicals damaging to stratospheric ozone were listed as class I and class II substances. Class I substances were separated into five groups, which include the following three groups containing fluorine: group I—chlorofluorocarbons (CFC's) 11, 12, and 113-115; group II—halons 1211, 1301, and 2402; and group III—CFC's 13, 111, 112, and 211-217. Class II substances consisted of hydrochlorofluorocarbons (HCFC's).

Production phaseout schedules were established for all class I substances limiting production to a percentage of that produced by the individual in the designated baseline year. The baseline year for groups I and II was 1986, and for group III it was 1989. Notwithstanding the scheduled termination of production, limited production and consumption of CFC 114 and the halons may be authorized for national security, aviation safety, fire suppression, and explosion prevention, if it is determined that no safe and effective substitute has been found.

TABLE 3

CFC PRODUCTION PHASEOUT

Year	Production limit[1]
1991	85%
1992	80%
1993	75%
1994	65%
1995	50%
1996	40%
1997	15%
1998	15%
1999	15%
2000	—

[1]Percentage of baseline year 1986 or 1989.

Although a specific phaseout schedule has not been established for class II substances, the law does state that as of January 1, 2015, production of all class II substances are limited to a percentage of that produced by the individual in an as yet to be selected baseline year. Effective January 1, 2030, it shall be unlawful for any person to produce any class II substance. The Environmental Protection Agency has until December 31, 1999, to promulgate regulations phasing out production and restricting the use of class II substances.

The phaseout schedules for both class I and class II substances can be accelerated if new scientific evidence warrants it, the availability of substitutes makes it practical, or the Montreal Protocol on Substances that Deplete the Ozone Layer is modified to include a phaseout schedule more accelerated than the one under this law.[4]

Issues

HF is used as a catalyst to convert low-molecular-weight byproduct hydrocarbons into larger hydrocarbons, such as 2,2,4-trimethylpentane. The resulting compound is called alkylate, and the process is called petroleum alkylation. Alkylate is a prime blending compound for high-octane gasoline.

The use of HF acid for petroleum alkylation and CFC refrigerant production in populated areas has come under intense scrutiny. Accidental releases of HF during transport have heightened the public's awareness of the potential danger from a major accident. The perceived danger from an accidental release of HF acid resulted in an out-of-court settlement between Torrance, CA, and Mobil Oil to end Mobil's use of HF at their refinery in Torrance by 1997. In a similar issue, the Southern Coast Air Quality Management District, the air regulatory panel for the four county Los Angeles area, voted on April 4, 1991, to ban HF use by refiners by the end of 1997 and by refrigerant manufacturers by the end of 1998. Interim controls are scheduled to go into effect January 1, 1992. The ban will take effect unless an additive is developed to prevent the formation of toxic vapor clouds. Four petroleum refineries and one refrigerant plant were impacted by the decision.[5]

The California bans have impacted primarily the petroleum refining industry. HF is used in about one-half of U.S. refineries. The alternative to HF in the alkylation process is sulfuric acid. The American Petroleum Institute estimated that, based on the average cost of a typical alkylation unit, it would cost about $4 billion to replace all existing HF alkylation units with sulfuric acid units. Switching from an HF process to a sulfuric acid process would most likely require construction of new alkylation units. Because most of the equipment used in the two processes is not interchangeable, conversion of an existing unit would require shutting down the unit for several months and special chemical cleaning of the few pieces of reusable equipment. Also, the space required for the new equipment would be difficult to find on the existing alkylation unit site. For these reasons, most refiners would decide to construct new alkylation units elsewhere in the refinery rather than convert the existing unit.[6]

If a ban or severe restrictions on usage were to spread throughout the United States, it would have a major economic impact on other industries that depend on HF as a feedstock or as a necessary

processing chemical. These would include the fluorochemical, aluminum, stainless steel, and uranium chemical industries.

Production

Illinois remained the leading producing State, accounting for about 95% of all U.S. shipments. Data on shipments of fluorspar by State and grade are withheld to avoid disclosing company proprietary data.

Ozark-Mahoning Co., the Nation's largest fluorspar producer and a subsidiary of Atochem North America Inc., operated three mines and a flotation plant in Pope and Hardin Counties, IL. Ozark-Mahoning also dried imported fluorspar to supplement its production. Seaforth Mineral & Ore Co. Inc. dried imported fluorspar at its facilities at Cave-In-Rock, IL, and East Liverpool, OH, for sale primarily to consumers in the ceramic industry. H. & H. Equipment and Engineering Co. produced and shipped metallurgical-grade fluorspar from its mine in Juab County, UT. J. Irving Crowell, Jr., & Son shipped a small amount of metallurgical-grade fluorspar from its Crowell-Daisy Mine in Nye County, NV.

Ozark-Mahoning reestablished production from the former Inverness Mining Co. Minerva #1 Mine. Overall, Ozark-Mahoning's production was evenly divided between the Minerva #1, Annabell Lee, and Denton Mines.

Seven plants processing phosphate rock for the production of phosphoric acid sold a reported 46,754 metric tons of byproduct fluosilicic acid at a value of about $5,855,000. This was equal to 82,287 metric tons of 92% fluorspar equivalent.

Reported and estimated production of fluorspar briquets for use in steel furnaces totaled about 108,000 metric tons valued at $10,700,000. Fluorspar briquets were produced by two plants owned by Cametco Inc., one plant owned by National Briquetting Co., one plant owned by Oglebay Norton Co., and one plant owned by Mercier Corp. The Mercier plant went out of business in 1990. Oglebay Norton also dried, packaged, and shipped imported ceramic- and acid-grade fluorspar.

Consumption and Uses

Acid-grade fluorspar, containing greater than 97% calcium fluoride (CaF_2), was used primarily as a feedstock in the manufacture of HF. Ceramic-grade fluorspar, containing 85% to 95% CaF_2, was used for the production of glass and enamel, to make welding rod coatings, and as a flux in the steel industry. Metallurgical-grade fluorspar, containing 60% to 85% or more CaF_2, was used primarily as a fluxing agent by the steel industry.

Reported domestic consumption by the HF industry decreased by about 18%. Reported consumption by the steel industry increased by about 5%, although the increase may have been simply the result of more accurate reporting. According to the American Iron and Steel Institute, domestic production of raw steel in 1990 remained essentially unchanged from 1989 levels.

In the ceramic industry, fluorspar was used as a flux and as an opacifier in the production of flint glass, white or opal glass, and enamels. Fluorspar was used in the manufacture of glass fibers, aluminum, cement, and brick, and was also used in the melt shop by the foundry industry.

Three companies reported fluorspar consumption for the production of HF. The U.S. Department of Commerce, Bureau of the Census, reported that, based on their monthly survey, anhydrous, technical, and aqueous HF, 100% basis, "produced and withdrawn from the system," was an estimated 136,000 metric tons for 1990 compared with the 1989 quantity of about 177,000 metric tons.

The largest use of HF was for the production of a wide range of fluorocarbon chemicals, including fluoropolymers and CFC's. CFC's were produced by five companies. According to preliminary data from the U.S. International Trade Commission, production of trichlorofluoromethane (CFC-11) decreased by 30% to 61,277 metric tons, dichlorodifluoromethane (CFC-12) decreased by about 47% to 94,586 metric tons, and chlorodifluoromethane (HCFC-22) decreased by about 6% to 138,830 metric tons, compared with 1989 figures.

As a consequence of the passage of the Clean Air Act Amendments, CFC-11 and CFC-12 production will be phased out during the next 10 years and may be phased out even sooner as discussed previously. Because HCFC-22 is not a fully halogenated CFC and has a much lower ozone-depletion potential, it was classified as a class II substance and will be phased out at a later date. The chemical industry continued to pursue research into replacement compounds for the CFC's and HCFC's that are to be phased out. Construction continued on commercial plants to manufacture some of the most promising replacements. The CFC producers are developing substitutes called hydrochlorofluorocarbons (HCFC's) that have ozone-depletion potentials of about 5% that of CFC-11, CFC-12, and CFC-113, which in total account for more than 90% of CFC consumption. Other substitutes, called hydrofluorocarbons (HFC's), have no ozone-depletion potential because they contain no chlorine atoms. The most likely candidates to replace controlled CFC's are HCFC-22, for use in home air-conditioning and plastic foams; HCFC-123, a potential substitute for CFC-11 in plastic foams and refrigeration; HFC-134a, a potential substitute for CFC-12 in refrigeration and auto air conditioners; and HCFC-141b, a potential substitute for CFC-11 in plastic foams. In addition, some of the replacements will be mixtures of these compounds and other HCFC's and HFC's. Only HCFC-22 is currently in commercial use. Inhalation and toxicity tests continued on the various replacements.

The manufacture of synthetic cryolite and aluminum fluoride for use in aluminum reduction cells was a major use of HF. In the Hall-Héroult process, alumina is dissolved in a bath of molten cryolite, aluminum fluoride, and fluorspar to allow electrolytic recovery of aluminum. An estimated 20 to 30 kilograms of fluorine was consumed for each metric ton of aluminum produced. Aluminum fluoride was used by the ceramic industry for some body and glaze mixtures and in the production of specialty refractory products. It was used in the manufacture of aluminum silicates and in the glass industry as a filler.

HF was consumed in the manufacture of uranium tetrafluoride that was used in the process of concentrating uranium isotope 235 for use as nuclear fuel and in fission explosives. It was also used in stainless steel pickling, petroleum alkylation, glass etching, oil and gas well treatment, and as a cleaner and etcher in the electronics industry. It was used as the feedstock in the manufacture of a host of fluorine chemicals used in dielectrics, metallurgy, wood preservatives, herbicides, mouthwashes, decay-preventing dentifrices, plastics, and water fluoridation.

Fluosilicic acid was used primarily in

TABLE 4

U.S. CONSUMPTION (REPORTED) OF FLUORSPAR, BY END USE

(Metric tons)

End use or product	Containing more than 97% calcium fluoride (CaF_2)		Containing not more than 97% calcium fluoride (CaF_2)		Total	
	1989	1990	1989	1990	1989	1990
Hydrofluoric acid (HF)	397,423	324,275	—	—	397,423	324,275
Iron and steel (foundries)						
Open hearth furnaces	—	—	4,534	3,336	4,534	3,336
Basic oxygen furnaces	W	—	24,528	19,993	24,528	19,993
Electric furnaces	—	—	74,356	83,142	74,356	83,142
Other[1]	1,635	2,013	32,778	36,786	34,413	38,799
Total	W	W	W	W	106,628	e95,000
Stocks, Dec. 31 (consumer)	W	W	W	W	641,882	564,545
	47,703	20,652	8,309	34,339	79,347	54,991

[1]Estimated. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes glass and fiberglass, enamel, welding rod coatings, primary aluminum, primary magnesium, other chemical products, other ceramic products, and other primary metals.

water fluoridation, either directly or after processing to sodium silicofluoride, and to make aluminum fluoride for the aluminum industry.

Stocks

Fluorspar consumer stocks decreased substantially from the previous year. Consumer stocks were 54,991 metric tons, down 31% from the level reported in 1989. Government stockpiles of fluorspar remained unchanged and contained a reported 891,957 short dry tons (809,171 metric tons) of acid grade and 294,045 short dry tons (266,753 metric tons) of metallurgical grade. The Government stockpiles also include 899 short dry tons (816 metric tons) of nonstockpile, acid-grade material and 116,777 short dry tons (105,938 metric tons) of nonstockpile, metallurgical-grade material. The Defense Logistics Agency attempted unsuccessfully to sell some of the latter in 1990.

Prices

According to prices published by Industrial Minerals (Metal Bulletin PLC), the price of domestic acid-grade fluorspar increased by about $5 per metric ton. Published foreign producer prices at yearend were essentially unchanged compared with 1989 prices. Although not published in 1990, prices for Chinese fluorspar were reported to be 20% to 30% below the published prices.

Yearend price quotations from the Chemical Marketing Reporter (CMR) were unchanged at $0.6875 per pound for anhydrous HF and were unchanged at $52.00 per 100 pounds for aqueous HF, 70%, in tanks. These quotations were equivalent to about $1.52 per kilogram for anhydrous HF and $114.64 per 100 kilograms for aqueous HF, 70%, in tanks. The CMR yearend price quotation for fluosilicic acid, 100% basis, in tanks, was unchanged at $340 per short ton (about $375 per metric ton) and for synthetic cryolite was unchanged at $550 per short ton (about $606 per metric ton).

Foreign Trade

According to the Bureau of the Census, U.S. exports of fluorspar increased by 191% and had an average value of $127 per metric ton. More than 11,000 metric tons were exported to Canada, which received 76% of U.S. fluorspar exports.

Imports for consumption of fluorspar decreased by about 22%, with Mexico remaining the most important supplier, followed by, in descending order of the quantity imported, China, the Republic of South Africa, Canada, Morocco, and Kenya. The average unit value, in dollars per metric ton, was $135 for acid grade and about $102 for subacid grade.

U.S. import duties underwent major changes in 1990. Presidential Proclamation 6123 of April 26, 1990, made acid-grade fluorspar from Mexico eligible for preferential tariff treatment under the Generalized System of Preferences, pursuant to Title V of the Trade Act of 1974,

TABLE 5

PRICES OF DOMESTIC AND IMPORTED FLUORSPAR

(Dollars per metric ton)

	1989	1990
Domestic, f.o.b., Illinois district, bulk, acid-grade	185–191	190–195
Mexican, f.o.b., Tampico:		
Acid-grade, filtercake	130–135	135
Metallurgical-grade	90	90–95
South African, f.o.b., Durban, acid-grade, dry basis	130–140	130–140

Source: Industrial Minerals (Metal Bulletin PLC), No. 268, Jan. 1990, p. 66 and No. 280, Jan. 1991, p. 66.

TABLE 6

U.S. EXPORTS OF FLUORSPAR, BY COUNTRY

Country	1989		1990	
	Quantity (metric tons)	Value	Quantity (metric tons)	Value
Australia	208	$22,961	72	$12,662
Canada	4,317	546,944	11,354	1,385,153
Colombia	—	—	55	6,200
Dominican Republic	190	34,886	637	155,398
Ghana	57	14,670	—	—
India	28	37,600	—	—
Indonesia	43	4,706	—	—
Israel	—	—	254	27,983
Mexico	261	28,695	814	104,215
Taiwan	—	—	539	59,290
United Kingdom	—	—	545	60,099
Venezuela	30	3,900	651	79,666
Total	5,134	694,362	14,921	1,890,666

Source: Bureau of the Census

as amended. Effective July 1, 1990, this material was exempted from duty upon entering the United States. The preferential tariff treatment applies as long as Mexico's share of the import market does not exceed 50% or $89.9 million.[7] Effective on August 20, 1990, the 13.5% ad valorem tariff on imports of all metallurgical-grade fluorspar was suspended through December 31, 1992. The suspension was provided for in Public Law 101-382, Customs and Trade Act of 1990, Title III, Part 1, Section 450F, signed into law August 20, 1990.[8]

Imports for consumption of HF decreased about 11% to a quantity equivalent to approximately 153,000 metric tons of fluorspar. Imports of synthetic and natural cryolite decreased 11% to a quantity equivalent to approximately 8,800 metric tons of fluorspar. Imports of aluminum fluoride decreased about 22% to a quantity equivalent to approximately 54,000 metric tons of fluorspar.

TABLE 7

U.S. IMPORTS OF FLUORSPAR, BY COUNTRY AND CUSTOMS DISTRICT

Country and customs district	1989		1990	
	Quantity (metric tons)	Value[1] (thousands)	Quantity (metric tons)	Value[1] (thousands)
CONTAINING MORE THAN 97% CALCIUM FLUORIDE (CaF_2)				
Brazil: Houston	—	—	5,433	$354
Canada:				
Houston	17,737	$2,152	6,360	753
New Orleans	20,975	3,067	15,777	2,433
Total	38,712	5,219	22,137	3,186
China:				
Houston	68,051	7,912	57,791	7,524
Laredo	6,402	736	—	—
New Orleans	84,853	10,492	67,397	8,920
Portland	—	—	2	6
Total	159,306	19,140	125,190	16,450
France:				
New York	18	7	54	51
Philadelphia	—	—	90	41
Total	18	7	144	92
Germany, Federal Republic of:				
Wilmington	1	11	6	12
Kenya: Houston	4,830	579	8,800	1,234
Mexico:				
Buffalo	—	—	949	106
El Paso	r64,658	r6,674	46,895	5,793

See footnotes at end of table.

TABLE 7—Continued

U.S. IMPORTS OF FLUORSPAR, BY COUNTRY AND CUSTOMS DISTRICT

Country and customs district	1989		1990	
	Quantity (metric tons)	Value[1] (thousands)	Quantity (metric tons)	Value[1] (thousands)
CONTAINING MORE THAN 97% CALCIUM FLUORIDE (CaF_2)—Continued				
Mexico—Continued				
Houston	34,115	3,731	17,581	2,259
Laredo	64,165	7,799	63,306	8,386
New Orleans	20,853	2,585	13,531	1,609
Philadelphia	612	64	—	—
San Diego	—	—	702	79
Total	184,403	20,853	142,964	18,232
Morocco: New Orleans	38,145	5,430	10,950	r1,533
Namibia: Houston	—	—	4,229	422
South Africa, Republic of:				
Houston	10,382	1,453	—	—
New Orleans	106,909	15,914	86,660	13,516
Total	117,291	17,367	86,660	13,516
Spain: New Orleans	11,097	1,791	—	—
Grand total	553,803	70,397	406,513	55,031
CONTAINING NOT MORE THAN 97% CALCIUM FLUORIDE (CaF_2)				
Canada:				
Detroit	—	—	34	4
Seattle	160	23	—	—
Total	160	23	34	4
China: New Orleans	2,860	243	28,088	2,518
Mexico:				
Baltimore	12,616	1,331	5,699	641
Buffalo	—	—	325	30
Detroit	—	—	34	3
El Paso	r5,894	r385	17,153	1,171
Houston	72	4	—	—
Laredo	8,381	579	683	65
New Orleans	71,519	6,890	41,265	4,529
Philadelphia	—	—	5,757	541
Seattle	285	45	90	158
Total	98,767	r9,234	71,006	7,138
South Africa, Republic of: New Orleans	—	—	8,280	1,247
Grand total	101,787	r9,500	107,408	10,907

rEstimated. rRevised.
[1]C.i.f. value at U.S. port.

Source: Bureau of the Census.

An application was submitted to the Foreign Trade Zones Board, Department of Commerce, requesting a special-purpose subzone status for the alumina and aluminum fluoride manufacturing plant of the Aluminum Co. of America (Alcoa) in Calhoun County, TX, adjacent to the Point Comfort Customs point of entry. Zone procedures would exempt Alcoa from customs duty payments on foreign material used in its exports. On domestic sales, the company would be able to choose the finished product duty rate that applies to aluminum fluoride (duty free) rather than the rate on fluorspar ($2.07 per metric ton).[9]

World Review

World fluorspar consumption and production decreased compared with 1989 levels. In order of rank, China, Mongolia,

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF HYDROFLUORIC ACID (HF), BY COUNTRY

Country	1989		1990	
	Quantity (metric tons)	Value[1] (thousands)	Quantity (metric tons)	Value[1] (thousands)
Canada	33,858	$37,416	24,629	$29,284
Germany, Federal Republic of	74	172	47	123
Japan	1,202	1,651	1,016	1,567
Malawi	19	21	—	—
Mexico	82,804	77,588	75,362	77,513
Monaco	68	73	—	—
United Kingdom	877	998	738	861
Total	r118,902	r117,919	101,792	109,348

rRevised.
[1]C.i.f. value at U.S. port.

Source: Bureau of the Census.

TABLE 9

U.S. IMPORTS FOR CONSUMPTION OF CRYOLITE, BY COUNTRY

Country	1989		1990	
	Quantity (metric tons)	Value[1] (thousands)	Quantity (metric tons)	Value[1] (thousands)
Australia	—	—	435	$271
Canada	251	$1,759	835	634
China	—	—	128	101
Denmark	3,941	3,690	2,335	2,314
Germany, Federal Republic of	70	919	874	720
Iceland	—	—	559	631
Japan	—	—	2,090	2,062
Netherlands	45	561	11	16
Other	11	157	39	26
Total	[2]8,429	[2]7,647	7,306	6,775

[1]C.i.f. value at U.S. port.
[2]Total includes synthetic cryolite imports, data not available by country.

Source: Bureau of the Census.

Mexico, the U.S.S.R., and the Republic of South Africa were the major producers. The international fluorspar industry suffered the initial effects of major changes in traditional markets. Some smaller producers have closed or were in danger of closing because of shrinking markets and price pressures from Chinese suppliers.

Canada.—St. Lawrence Fluorspar Ltd., subsidiary of Minworth Group PLC, London, England, ceased production. Mine production was halted in the third quarter, and the company was put into receivership in January 1991. Pumping stopped in early April 1991, and the mine was allowed to flood. The company had been in production for less than 4 years. Initial production began in 1987 from the Tarefare vein open pit and the Blue Beach North underground mine. The operation produced mainly acid-grade fluorspar, with most being exported to the United States.

China.—Fluorspar exports from China continued at high levels, with reported exports of 1,094,000 metric tons in 1989. Based on reported export data and estimates of domestic consumption, it is estimated that China produced about 1.5 million metric tons in 1990. U.S. imports from China decreased by about 4% to 153,000 metric tons. China's largest export market remained Japan, although exports to Japan were down by 20% compared with those of 1989. China produces from 15 Provinces, has reserves reportedly in excess of 100 million metric tons, and routinely undercuts all other producers in price. Metallurgical-grade material at 90% CaF_2 was offered in Northern Europe at $90 per metric ton, c.i.f., and acid-grade material was offered at $100 to $105 per metric ton, c.i.f.

Zhejiang Province is one of the major fluorspar-producing Provinces in China. The major fluorspar area is the Wu Yi fluorspar district in central Zhejiang Province. The Dong Feng Fluorite Co., owner and operator of the principal mines and mill, is under the Ministry of Metallurgical Industry. The company operates 14 active mines producing about 600,000 metric tons of ore with an average ore to waste ratio of 1.3:1. They produce on average about 90,000 metric tons of metallurgical grade and 235,000 of acid grade per year.

Denmark.—After more than 130 years, Denmark's production of natural cryolite from the Ivigtut Mine in Greenland has ceased. Mine production ended some years ago, but Kryolitselskabet Oresund A/S, with the Danish State as co-shareholder since 1940, continued to process material stockpiled in Greenland and at its Strandboulevarden plant in Copenhagen. In late 1990, the last of the plant stockpile was worked out. Cryolite, sodium aluminum fluoride Na_3AlF_6, is necessary for the electrolytic recovery of aluminum.

Mexico.—Official production figures for Mexico as shown in table 11 were provided by Consejo de Recursos Minerales (the Mexican Council of Mineral Resources). The data tend to be about 10% below industry-supplied figures and do not present the data in a breakdown by grade normally used by the fluorspar industry. The Instituto Mexicano de Zinc, Plomo y Coproductos A.C., collects fluorspar data for the fluorspar industry. According to their numbers, Mexico produced 207,000 metric tons of metallurgical grade and 488,000 metric tons of acid grade in 1990. More than 60% of Mexico's production came from Cia.

TABLE 10

U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM FLUORIDE, BY COUNTRY

Country	1989		1990	
	Quantity (metric tons)	Value[1] (thousands)	Quantity (metric tons)	Value[1] (thousands)
Canada	8,477	$8,276	5,023	$5,259
China	1,460	1,063	2,035	1,654
France	2,700	3,715	2,495	3,094
Italy	—	—	1,010	2,454
Japan	8,006	7,939	5,303	6,162
Mexico	22,069	20,491	16,712	18,961
Norway	1,000	1,024	1,999	2,061
United Kingdom	408	185	522	230
Other	1,351	1,378	505	420
Total	45,471	44,071	35,604	40,295

[1] C.i.f. value at U.S. port.

Source: Bureau of the Census.

Minera Las Cuevas S.A. de C.V. and Fluorita de México S.A. Mexico exported in excess of 300,000 metric tons in 1990, of which more than 60% was shipped to North America.

In May 1990, Industrial Químicas de México S.A. de C.V., a wholly owned subsidiary of Rhne-Poulenc S.A., announced plans for construction of a new HF and xanthate plant in Coahuila, Mexico. The plant was to be completed by the end of 1992 and have a final HF capacity of 60,000 metric tons. Construction plans have now been suspended indefinitely because of changed economic conditions and reduced demand.

Current Research

The U.S. Bureau of Mines, through its basic research program, has investigated column flotation for recovery of high-grade fluorspar concentrate and byproduct

TABLE 11

FLUORSPAR: WORLD PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country	1986	1987	1988	1989	1990[e]
Argentina	39,076	r54,975	r18,052	r23,317	20,000
Brazil (marketable):					
Acid grade	53,555	58,736	54,050	r56,973	55,000
Metallurgical grade	31,059	31,212	35,310	r38,558	35,000
Total	84,614	89,948	89,360	r95,531	90,000
Canada: Acid grade[e]	—	10,000	40,000	50,000	25,000
China:[e]					
Acid grade	450,000	550,000	950,000	1,200,000	1,200,000
Metallurgical grade	450,000	450,000	450,000	500,000	300,000
Total	r900,000	1,000,000	1,400,000	1,700,000	1,500,000
Czechoslovakia[e]	95,000	95,000	95,000	95,000	95,000
Egypt	80	776	1,849	r1,721	1,700
France:					
Acid and ceramic grades	148,000	134,000	r153,000	r159,000	155,000
Metallurgical grade[e]	50,000	50,000	50,000	50,000	50,000
Total	198,000	184,000	r[e]203,000	r[e]209,000	205,000
Germany, Federal Republic of:					
Western states (marketable)	88,834	85,201	r77,710	r[e]74,500	74,600
Eastern states[e]	100,000	90,000	90,000	90,000	70,000
Total[e]	188,834	175,201	167,710	164,500	144,600
Greece[e]	r150	200	200	200	150
India:					
Acid grade	7,633	8,259	r8,823	r10,300	10,400
Metallurgical grade	4,100	4,450	r6,772	r12,589	12,500
Total	11,733	12,709	r15,595	r22,889	22,900

See footnotes at end of table.

TABLE 11—Continued

FLUORSPAR: WORLD PRODUCTION, BY COUNTRY[1]

Country	1986	1987	1988	1989	1990[2]
Iran[3]	r7,352	r6,483	26,350	r,e25,000	25,000
Italy:					
Acid grade	90,900	77,800	81,700	r66,600	67,000
Metallurgical grade	54,536	56,600	58,157	r59,679	61,000
Total	145,436	134,400	139,857	r126,279	128,000
Kenya: Acid grade	37,146	61,504	99,092	r95,181	95,000
Korea, North: Metallurgical grade[e]	40,000	40,000	40,000	40,000	40,000
Korea, Republic of: Metallurgical grade	243	r63	261	r856	900
Mexico:[3]					
Acid grade	423,614	r409,846	r338,000	r359,000	285,000
Ceramic grade	13,593	12,015	r27,000	r27,000	22,000
Metallurgical grade	263,152	306,633	r253,000	r225,000	201,000
Submetallurgical grade	66,463	95,398	r138,000	r168,000	126,000
Total	766,822	823,892	r756,000	r779,000	r634,000
Mongolia: Metallurgical grade[e]	790,000	800,000	800,000	r750,000	750,000
Morocco: Acid grade	83,000	r78,000	100,500	r105,000	105,000
Namibia: Acid grade	—	—	r,e1,500	r,e15,000	30,000
Pakistan	4,353	r3,528	264	r4,741	4,700
Romania: Metallurgical grade[e]	20,000	18,000	18,000	16,000	15,000
South Africa, Republic of:					
Acid grade	293,368	r279,000	282,986	r,e310,000	262,000
Ceramic grade[e]	r7,703	7,000	8,000	r9,000	7,500
Metallurgical grade[e]	r32,814	30,606	37,435	r49,340	41,532
Total	333,885	316,606	328,421	368,340	r311,032
Spain:					
Acid grade	257,108	147,757	r137,140	r,e130,000	130,000
Metallurgical grade	25,352	23,859	r5,435	r,e5,000	5,000
Total	282,460	171,616	r142,575	r,e135,000	135,000
Sweden	265	220	225	r150	150
Thailand:					
Acid grade	11,500	—	—	—	—
Metallurgical grade	156,409	102,398	76,321	r98,375	100,000
Total	167,909	102,398	76,321	r98,375	100,000
Tunisia: Acid grade	36,828	32,653	r55,416	r53,575	53,000
Turkey: Metallurgical grade[e]	r,e1,604	10,000	r13,240	13,000	13,000
U.S.S.R.[4]	r,e410,500	410,500	r,e410,500	410,000	380,000
United Kingdom	133,420	120,400	103,797	r122,057	120,000
United States: shipments[5]	71,000	63,500	63,500	66,000	63,500
Grand total	r4,849,710	r4,816,572	r5,206,605	r5,585,712	5,106,632

[e]Estimated. [r]Revised.
[1]Table includes data available through May 24, 1991.
In addition to the countries listed, Bulgaria is believed to have produced fluorspar in the past, but production is not officially reported, and available information is inadequate for the formulation of reliable estimates of output levels.
[2]An effort has been made to subdivide production of all countries by grade (acid, ceramic, and metallurgical). Where this information is not available in official reports of the subject country, the data have been entered without qualifying notes.
[3]Reported figure.
[4]Year beginning Mar. 21 of that stated.
[5]Data for 1986–87 were provided by the Instituto Mexicano de la Fluorita (now disestablished). Data for 1988–89 and total for 1990 are as reported by Consejo de Recursos Minerales.

concentrates from a marginal deposit in Nevada. A sample of about 4,500 kilograms was obtained from the Fish Creek fluorspar deposit in Eureka County, NV, grading about 14% CaF_2. The recovery process consisted of (1) grinding the ore, (2) fluorspar rougher and cleaner flotation, (3) desliming the rougher fluorspar flotation tailings, (4) mica flotation, and (5) silicate rougher flotation. Acid-grade fluorspar, mica, silica sand, and low-grade beryl concentrate were recovered. In addition to technical research, the Bureau conducted a cost evaluation on the use of column flotation to recover fluorspar only from the deposit.[10]

OUTLOOK

There are three major sectors of fluorspar demand: metallurgical-grade fluorspar and briquets by the steel industry; acid-grade fluorspar by the aluminum industry, primarily for production of aluminum fluoride; and acid-grade fluorspar by the chemical industry for production of feedstock HF.

Consumption of fluorspar by the steel industry is difficult to quantify. The problem is compounded by the large number of steel mills, the industry's often times indifferent response to consumption surveys, and the lack of accurate data on fluorspar briquets. Consumption of fluorspar by the steel industry has declined dramatically since the introduction of the basic-oxygen furnace and the gradual obsolescence of the open-hearth furnace. Some companies have reported that with certain new furnaces fluorspar use will be unnecessary. Domestically, steel production is expected to be down by 5% to 10% in 1991 owing to the economic recession. A recovery is expected by the end of the year, but many economists are predicting only a weak recovery. As such, it is estimated that overall consumption of metallurgical-grade fluorspar by the steel industry will be flat or continue to decrease during the next 3 to 5 years.

The aluminum industry consumes fluorine from different sources and in different forms. Although some fluorspar is consumed directly, fluorine is also consumed in the form of aluminum fluoride and synthetic or natural cryolite. Aluminum fluoride is manufactured either directly from fluorspar, from HF, or from fluosilicic acid. A small amount of cryolite is imported for consumption, but most is recovered as a byproduct of waste fluorine recovery or, in the case of a new potline, by tapping an operating pot for molten electrolyte. This material, termed "molten crushed bath," is allowed to solidify and is then crushed for use in the startup of a new potline.

The domestic aluminum industry is currently operating at or above rated capacity. No expansion of capacity is anticipated in the next few years, and the consumption of fluorspar and fluorine chemicals by the aluminum industry is expected to remain at current levels during the next 3 to 5 years.

Consumption of acid-grade fluorspar by the chemical industry for the production of HF is the largest market for fluorspar. The largest use of HF is in the manufacture of fluorocarbons (CFC's, HCFC's, and HFC's); the reminder is used in chemical intermediates, glass and metal processing, petroleum alkylation, stainless steel pickling, uranium chemical production, and other small uses. The initial effects of the CFC phaseout are being felt as was demonstrated by the 18% decrease in fluorspar consumption by the HF industry in 1990. It may be too early to judge whether the forecasts for large increases in HF consumption for production of replacement HCFC's and HFC's were far off the mark. Yet, the number and variety of not-in-kind replacements undergoing research or ready for development seem to be growing rapidly. Other forecasts have been more pessimistic from the start and anticipated that any gains in HF consumption for HCFC's and HFC's would be offset by overall decreases in CFC usage. In the short term, fluorspar consumption by the fluorocarbon industry is expected to be at much reduced levels from just a few years ago.

Some areas of HF consumption that are expected to grow are production of fluoropolymers, fluoroelastomers, and new fluorine-containing agricultural and pharmaceutical chemicals. The demand for fluoropolymers and fluoroelastomers could grow by 10% per year in the next 3 to 5 years. Industry estimates project the combined number of potential fluorine-containing drugs and agrochemicals at more than 500. Unfortunately, these markets only account for a small percentage of HF consumption, and it is highly unlikely these markets will be able to absorb the losses expected in the fluorocarbon sector.

[1]K'gore, C. C., S. R. Kramer, and J. A. Bekkala. Fluorspar Availability—Market Economy Countries and China. BuMines IC 9060, 1985, pp. 16 and 17.

[2]Work cited in footnote 1.

[3]U.S. Congress. Illinois Wilderness Act of 1990. Public Law 101-633, Nov. 28, 1990, 104 Stat. 4577.

[4]U.S. Congress. Clean Air Act Amendments of 1990. Public Law 101-549, Nov. 15, 1990, 104 Stat. 2399.

[5]Sternberg, K. Use of Hydrofluoric Acid Comes Under the Gun in California. Chem. Week, v. 147, No. 17, 1990, p. 26.

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[8]U.S. Congress. Customs and Trade Act of 1990. Public Law 101-382, Aug. 20, 1990, 104 Stat. 629.

[9]Federal Register. Foreign Trade Zones Board (Dep. Commerce). Foreign Trade Zone 155—Calhoun-Victoria Counties, TX; Application for Subzone; Alcoa Alumina and Aluminum Fluoride Plant. V. 55, No. 35, Feb. 21, 1990, p. 6027.

[10]Peterson, M. L. Duchene, and M. Shirts. Column Flotation of Multiple Products From a Fluorite Ore. BuMines RI 9309, 1990, 22 pp.

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